Content of Ph.D. Qualifying Exam

Department of Physics, METU

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This document provides a non-exhaustive list of topics covered by the Ph.D. qualifying exam.

All Ph.D. students preparing to take the qualifying exam are assumed to have good knowledge of subject matters covered by the following undergraduate level courses

- Phys 209: Mathematical Methods in Physics I
- Phys 210: Mathematical Methods in Physics II
- Phys 202: Modern Physics
- Phys 221: Optics and Waves
- Phys 300: Quantum Physics
- Phys 311: Classical Mechanics
- Phys 334: Electromagnetic Theory
- Phys 430: Statistical Thermodynamics
- Phys 431: Quantum Mechanics I

- Harmonic oscillator
- Particle in a box
- Three-dimensional central potentials, the radial equation and Hydrogen atom
- Postulates of quantum mechanics, measurement, collapse and uncertainty principle
- Calculations of commutators and their interpretation
- Time dependence of the wavefunctions, expectation values and conservation laws
- Schrödinger, Heisenberg and interaction pictures
- Continuous symmetries and their connection to degeneracy and conservation laws
- Discrete symmetries
- Angular momentum and rotation operators, addition of angular momentum
- Spin in external magnetic field
- Spin-orbit coupling
- Tensor operators and the Wigner-Eckart theorem
- Charged particles in an electromagnetic field and gauge transformations
- Relativistic quantum mechanics and Dirac equation (including its historical development and non-relativistic limit)
- Symmetry of wavefunctions for fermions and bosons.
- Time-independent and dependent perturbation theories, Fermi's golden rule
- Variational method, WKB and adiabatic approximations
- Scattering theory, Born approximation and optical theorem
- Coulomb's law and electrostatics
- Method of images
- Boundary-value problems in electrostatics, separation of variables
- Laplace and Poisson equations and Green's function method
- Electrostatics in macroscopic media
- Multipole expansion
- Biot-Savart law and magnetostatics
- Boundary-value problems in magnestostatics
- Induction
- Magnetostatics in macroscopic media
- Maxwell displacement current, Maxwell's equations and electrodynamics
- Gauge transformations, Lorenz and Coulomb gauges
- Retarded potentials, Lienard-Wiechert Potentials and fields for a point charge
- Conservation of energy and momentum for a system of electromagnetics fields and charged particles, Poynting's theorem
- Electromagnetic waves in vacuum and waveguides
- Reflection and refraction of electromagnetic waves across interfaces
- Radiation due to electric and magnetic dipoles and electric quadrupoles, multipole radiation
- Scattering at long wavelengths
- Special theory of relativity and covariant formulation of electrodynamics
- Lagrangian and Hamiltonian for a relativistics charged particle in electromagnetic field
- Lagrangian formulation of the electromagnetic field

- Power radiated by an accelerated charge and Larmor's formula

- Hamilton's principle (principle of least action), Lagrangian formalism and equations of motion
- Classical symmetries and conservation laws, cyclic coordinates
- Inertial and non-inertial frames of reference, fictitious forces
- Lagrange formulation with constraints
- Calculus of variations, D'Alembert's principle
- Bounded, unbounded central-force motions and Kepler's laws
- Rigid-body motion, inertia tensor, principal axes and Euler's equations
- Coupled oscillation and normal modes
- Hamiltonian formulation
- Canonical transformations, Poisson brackets and generating functions
- Hamilton-Jacobi theory and action-angle variables

- Basic laws of thermodynamics (from 0th to 3rd), heat engines and heat pumps, reversible and irreversible processes, entropy
- Thermodynamical potentials and Legendre transform
- Microcanonical, canonical and grand canonical ensembles (for both classical and quantum systems)
- Equipartition theorem
- Equilibrium properties from the partition function
- Gibbs' paradox, identical particles
- Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann distributions
- Ideal classical gases and ideal quantum (fermion and boson) gases, degenerate gases
- Bose-Einstein condensation
- Black-body radiation, Planck distribution
- Phase transitions and Clausius-Clapeyron relation

- Functions of a complex variable, analytic functions, multivalued functions, branch points and cuts
- Cauchy's Integral theorems and theory of residues and evaluation of real definite integrals
- Bessel functions, their representations and properties
- Gamma and related functions
- Legendre, Hermite and Laguerre polynomials; their representations and properties
- Partial differential equations and boundary value problems
- Green's function methods for solving partial differential equations
- Sturm-Liouville theory
- Fourier series and transforms
- Dirac delta function and its representations and properties
- Calculus of variations
- Integral transforms